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HUMAN BIOLOGICAL SURVEY

Body composition in offspring of New Zealand women: ethnic and gender differences at age 1–3 years in 2005–2009

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Abstract

Background: In multi-ethnic New Zealand the prevalence of obesity and diabetes is increasing and varies by ethnic group.
Aim: This study explored ethnic and gender differences in body composition in offspring of women treated for gestational diabetes in the metformin in gestational diabetes (MiG) trial.
Sample and methods: Total and regional body composition measured by dual X-ray absorptiometry were investigated in European, Indian, Polynesian and "Other" children aged 2 years (48 boys; 56 girls).
Results: By ethnicity, boys were not different by height or weight. Compared with European girls, Indian girls weighed less (2.3 ± 0.58 kg) and Polynesian (1.13 ± 0.53 kg) more, but percentage body fat was not different. Adjusted for age, height and weight boys had less total and appendicular fat and higher abdominal fat mass and total bone mineral density than girls ($p < 0.001$). Adjusted for age, weight and height Indian boys had more fat in the central and abdominal regions and less total lean mass than European boys ($p < 0.05$).
Conclusion: These measurements provide early evidence for gender and ethnic differences in the distribution of fat and might help identify who is most likely to benefit from intervention in the first few years of life to reduce risk of chronic disease including diabetes.

Keywords

Body composition, body fat, dual-energy X-ray absorptiometry, ethnicity, gender, lean mass, young children

History

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Background

Across the lifecycle, ethnic differences in size and body composition are increasingly recognized as an important factor to consider in relation to risk for cardiovascular disease and diabetes (Wells, 2012; Whincup et al., 2002). For example, Indians, compared with Europeans, have increased body fat percentage and decreased lean mass at any body mass index (BMI) (Rush et al., 2009; Yajnik et al., 2003), which may explain their increased risk of diabetes at a lower BMI. Polynesian children (Rush et al., 2003a,b) and adults (Rush et al., 2009) have an increased lean mass for a given BMI, but they reach higher BMIs than other populations and they also have higher rates of type 2 diabetes (Ministry of Health, 2012).

From birth, one of the most important influences on body size and composition is sex (Wells, 2007). In adults, females are more adipose than males and have a lower percentage of lean mass (Rush et al., 2009). However, females typically store their fat more peripherally than males and the additional fat stores may provide some metabolic protection (Kloting et al., 2010).

In multi-ethnic New Zealand the prevalence of obesity is increasing (Ministry of Health, 2012) and is a major risk factor for type 2 diabetes. Furthermore, the prevalence of obesity in children and adults continues to rise; one in nine children and one in three adults are obese (Ministry of Health, 2012). One in 12 pregnancies are complicated by gestational diabetes mellitus (GDM) and, for Pacific, Māori and Indian, the risk is 2–4-fold higher than that for European (National Women's Annual Clinical Report, 2012, 2013), similar to the ethnic differences in risk for diabetes in adults (Ministry of Health, 2012).

Obesity is inter-generational (Cnattingius et al., 2012) and, to inform interventions to break the vicious cycle, it is important to understand ethnic differences in the growth trajectory and patterns of accumulation of body fat from birth, through childhood and into adult life. However, there is a lack of appropriate techniques to measure body composition in early childhood (Wells, 2007). Therefore, there is a paucity of accurate information in the literature about any differences by gender and ethnicity of body composition of 1–3 year olds. Dual X-ray absorptiometry (DEXA) provides accurate

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measures of body fat, but has the limitation of not distinguishing visceral from subcutaneous fat tissue and, for young children, there is the challenge of having the child remain still for the duration of the scan.

The Metformin in Gestational Diabetes: The Offspring Follow-Up (MiGTOFU) is a longitudinal study of children born to women with gestational diabetes who were randomized to metformin or insulin treatment. At birth, for the women in the metformin group, compared with the insulin treatment, there were no increases in perinatal complications or differences in infant anthropometry (Rowan et al., 2008). At the 2-year follow-up there were no differences by treatment in total or percentage body fat measured by DEXA (Rowan et al., 2011) controlling for ethnic group. We aimed to investigate, in more detail, gender and ethnic differences in body composition measured by dual X-ray absorptiometry in these 2-year old offspring.

Sample

At the MiGTOFU 2-year old follow-up, 212 New Zealand children (107 boys, 105 girls) from a range of ethnic backgrounds with a mean age of 2.3 years (range = 1.1–3.3) were measured and 104 (48 boys, 56 girls) children scanned with minimal movement artefact for this analysis. Ethnicity of the child was determined from the self-reported ethnic groups of both parents and prioritized as ''Polynesian'', ''Indian'', ''Europeans'' and ''Other''. Both parents of the European ($n = 38$) and Indian ($n = 20$) groups identified with the same ethnic group. The Polynesian group consisted of 26 Pacific and two Maori children. The ''other'' group ($n = 18$) was predominantly of South East Asian ethnicity, with eight Chinese, one Filipino, one Laotian and eight children of other or mixed ethnicity.

Data collection

Baseline data relating to maternal HbA1c levels at recruitment, glucose control during pregnancy and customized birth weight percentiles were obtained from the initial MiG trial database, so that adjustment for these factors could be made if different between ethnic groups.

Anthropometric measurements

Weight (Tanita System 502, Tokyo, Japan) and standing height (stadiometer, Mentone, Moorabbin, Australia) were measured. Two readings (to the nearest 0.1 cm and 0.1 kg) were made for each measurement and the average of the two used. A third measurement was carried out if the difference between the first two height measurements was greater than 0.5 cm or weight measurements greater than 0.5 kg. In this case, the average of the three measurements was used.

Whole body DEXA scans were performed on a Lunar Prodigy 2000 scanner (General Electric, Madison, WI, software version 4.80x6.50). Children were not restrained or anaesthetized for the scan. Each scan was graded by a single operator and only scans with no movement or minimal movement were included. Total fat, lean and bone mineral content were determined and total fat free mass calculated from total body mass less fat mass. A single operator analysed the scans; the software generated defaults were not used. Appendages were isolated from the trunk and head by using cut lines to define the arms (i.e. soft tissue extending from the centre of the arm socket to the phalange tips) and legs (i.e. soft tissue extending from an angle drawn through the axis of the femoral neck and extended to the level of the pelvic brim to the phalange tips). The fat mass of the trunk plus head (central fat mass) was calculated as total fat mass less the fat mass of both arms and both legs. Abdominal and thigh regions of interest were defined by the criteria of Ley et al. (1992). The abdominal fat measure was obtained from analysis of a region positioned with the lower horizontal border on top of the iliac crest and the upper border approximately parallel with the junction of the T12 and L1 vertebrae. The sides of this region were adjusted to include the maximum amount of abdominal tissue. The thigh measure was obtained by analysing an area of identical height placed over the thighs, with the upper horizontal border positioned immediately below the ischial tuberosities. The lateral margins were adjusted to follow the shape of the thighs.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Northern Regional Ethics Committee. Written informed consent was obtained from all parents. The study was registered prior to its initiation under the Australasian Clinical Trials Registry (ACTRN 12605000311651).

Statistical analysis

For most analyses, unless stated, the children were analysed separately by gender because of the major effect of gender on body composition. Continuous variables are presented as mean standard deviation and range (minimum value, maximum value). One-way analysis of variance (ANOVA) was used to test for differences in group means. Analysis of co-variance (ANCOVA) was used on DEXA measurements to adjust for height, weight and age when examining differences among ethnic groups. Post-hoc, the Tukey–Kramer test was used to determine which groups were different, adjusted for unequal group sizes. For some comparisons a few potential outliers/extreme values were identified. The tests were repeated without the outliers and no significant differences were found. Model residuals were examined for normal distribution and, for most of the data presented, the distributions were normal. The analysis was performed without the transformation of non-normal data due to the symmetry of model residuals. The significance level was set at 5%. The analysis was completed using R v2.14 software (R Development Core Team, 2011).

Results

Maternal HbA1c at recruitment into the MiG trial, glucose control on treatment and rates of large (>90th percentile) and small (<10th percentile) for gestational age infants at birth were not significantly different between the ethnic groups (data not shown).

Unadjusted body composition characteristics of the boys and girls are summarized by ethnicity in Tables 1 and 2 where the DEXA measurements are grouped by anatomical region and fat mass (FM), lean mass and bone mineral content

Table 1. Characteristics of boys from four ethnic groups (unadjusted).

Boys	European ($n=18$)		Indian ($n=12$)		Polynesian ($n=11$)		Other ($n=7$)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p Value
Anthropometry									
Age (years)	2.3	0.19	2.4	0.20	2.4	0.29	2.3	0.28	0.679
Height (cm)	90.7	5.7	90.7	3.74	91.1	4.53	87.6	2.49	0.409
Weight (kg)	14.0	2.3	13.2	2.4	14.4	1.1	12.7	1.2	0.229
BMI (kg/m^2)	16.92	1.41	16.00	1.95	17.40	0.95	16.51	1.51	0.150
DEXA									
DEXA-weight (g)	13 710	2119.0	12 920	2289.7	14 180	1107.4	12 370	1573.5	0.182
FM (g)	2141	640.3	2145	1155.4	2266	466.2	1908	885.9	0.837
FFM (g)	11 570	1627.9	10 780	1392.0	11 910	993.0	10 460	820.4	0.072
BMC (g)	394.2	77.5	389.8	68.9	408.9	55.0	364.9	46.2	0.602
BMD (g/cm^2)	0.71	0.03	0.70	0.02	0.71	0.04	0.70	0.03	0.650

DEXA, dual X-ray absorptiometry; FFM, fat-free mass; FM, fat mass; BMC, bone mineral content; BMD, bone mineral density.

Table 2. Characteristics of girls from four ethnic groups (unadjusted).

Girls	European ($n=20$)		Indian ($n=8$)		Polynesian ($n=17$)		Other ($n=11$)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p Value
Anthropometry									
Age (years)	2.2	0.25	2.3	0.18	2.4	0.26	2.4	0.23	0.260
Height (cm)	87.5	4.41	87.3	4.38	91.5	4.76	89.1	4.99	0.058
Weight (kg)	13.0	1.80	11.7	1.50	14.9	2.30	13.1	1.10	0.001
BMI (kg/m^2)	16.9	1.02	15.4	2.30	17.7	1.93	16.5	1.06	0.010
DEXA									
DEXA-weight (g)	12 580	1666.5	11 750	1741.8	14 680	207.5	128 300	1110.8	0.000
FM (g)	2206	914.8	1895	941.4	2979	1133.0	2453	454.7	0.029
FFM (g)	10 380	1073.5	9858	989.2	11 700	1197.5	10 380	1197.8	0.001
BMC (g)	348.1	63.5	337.9	37.0	400.5	81.6	358.0	73.6	0.083
BMD (g/cm^2)	0.70	0.05	0.70	0.01	0.70	0.05	0.70	0.05	0.870

DEXA, dual X-ray absorptiometry; FFM, fat-free mass; FM, fat mass; BMC, bone mineral content; BMD, bone mineral density.

(BMC) (which summed represent the total mass of that region). By ethnicity boys were not different by height or weight or age. Compared with European girls, Indian girls weighed less (2.3 ± 0.58 kg) and Polynesian (1.13 ± 0.53 kg) more, but percentage body fat was not different. Total fat and fat percentage was not different by ethnicity, but Polynesian girls had more total and appendicular lean mass on their arms and legs than Indian girls ($p < 0.001$).

When the DEXA measurements were adjusted for age, height and weight, girls had higher percentage body fat and higher total abdominal, thigh, central and leg fat mass than boys (Table 3). Boys had higher total and central lean mass and bone mineral density than girls ($p < 0.001$).

Within gender adjusted for age, height and weight, Indian boys had more fat mass in the central and abdominal regions and less total lean mass (~600 g) than European boys (Table 4, $p < 0.05$). Pacific and European girls were not different in their percentage body fat or total fat mass. Other and European girls had less lean mass than Pacific and other girls had a higher body fat percentage.

Table 3. Comparison of DEXA measurements between boys and girls, adjusted for age, height, weight and ethnicity.

	Boys ($n=48$)		Girls ($n=56$)		
	Mean	SE	Mean	SE	p Value
FM (g)	2103	65.5	2473	60.5	0.000
FM%	15.6	0.5	18.1	0.4	0.000
FFM (g)	11 175	65.5	10 805	60.5	0.000
Lean (g)	10 790	64.4	10 434	59.5	0.000
BMC (g)	385.0	5.6	370.7	5.2	0.068
BMD (g/cm^2)	0.71	0.01	0.68	0.01	0.004
Central FM (g)	1016	37.9	1206	35.1	0.000
Central Lean (g)	7343	50.1	6959	46.3	0.000
Central BMC (g)	282	4.0	263	3.7	0.001
Abdominal FM (g)	111	6.5	143	6.0	0.001
Thigh FM (g)	233	10.0	272	9.3	0.007
Abdominal/Thigh FM ratio	0.46	0.04	0.55	0.04	0.157
Arm FM (g)	189	11.5	187	10.7	0.929
Arm Lean (g)	870	13.7	851	12.6	0.303
Arm BMC (g)	25.9	1.0	24.4	0.9	0.281
Leg FM (g)	898	25.8	1080	23.9	0.000
Leg Lean (g)	2576	29.7	2624	27.4	0.244
Leg BMC (g)	77.4	2.7	83.6	2.5	0.101

DEXA, dual X-ray absorptiometry; FFM, fat-free mass; FM, fat mass; Lean, lean mass; BMC, bone mineral content; BMD, bone mineral density; Abdominal/Thigh, abdominal fat mass and Thigh fat mass ratio; Total, whole body; Central, whole body, excluding arms and legs; Arm, arms region; Leg, legs region; Thigh, thigh region; Abdominal, abdominal region.

Discussion and comments

In this multi-ethnic group of 2-year olds gender and ethnicity were important determinants of body composition. We have previously reported at age 2 years in these children that there was no difference in DEXA measures of adiposity according to treatment with metformin or insulin (Rowan et al., 2008).

Table 4. Comparison of DEXA measurements by ethnicity separated by gender and adjusted for age, weight and height.

	European		Indian		Polynesian		Other		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*p* Value
Boys									
Total FM (g)	2032	95.6	2404	120.3	1980	124.3	2194	157.0	0.074
Total FM%	14.9	0.6	17.2	0.8	14.8	0.8	15.9	1.0	0.116
Total FFM (g)	11 425	125.6	10 906*	158.1	11 547	163.3	11 201	206.2	0.038
Total Lean (g)	11 037	123.0	10 514*	154.8	11 154	159.9	10 800	202.0	0.032
Total BMC (g)	388.1	7.9	392.0	10.0	394.1	10.3	400.2	13.0	0.876
Total BMD (g/cm^2)	0.71	0.01	0.70	0.01	0.70	0.01	0.71	0.01	0.811
Central FM (g)	940	53.7	1175*	67.5	975	69.7	1110	88.1	0.049
Central Lean (g)	7620	98.4	7073*	123.9	7463	127.9	7357	161.6	0.014
Central BMC (g)	285.5	6.0	280.7	7.6	287.2	7.8	294.8	9.9	0.725
Abdominal FM (g)	104	9.7	134	12.2	101	12.6	124	15.9	0.193
Thigh FM (g)	238	14.5	247	18.2	225	18.8	243	23.8	0.854
Abdominal/Thigh FM ratio	0.46	0.03	0.51	0.04	0.46	0.04	0.46	0.05	0.770
Arm FM (g)	212	24.5	203	30.8	163	31.8	168	40.2	0.574
Arm Lean (g)	861	23.7	881	29.9	937	30.8	832	39.0	0.151
Arm BMC (g)	25.1	1.8	29.6	2.3	27.0	2.4	25.5	3.0	0.504
Leg FM (g)	880	37.6	1025	47.3	842*	48.8	916	61.7	0.057
Leg Lean (g)	2556	42.4	2560	53.3	2754	55.0	2611	69.5	0.037
Leg BMC (g)	77.4	2.1	81.8	2.7	79.8	2.8	79.8	3.5	0.654
Girls									
FM (g)	2413	107.6	2597	175.7	2272	128.2	2657	143.0	0.230
FM%	17.8	0.8	18.6	1.3	16.8	0.9	20.2	1.0	0.110
FFM (g)	10 736	107.6	10 553	175.7	10 878	128.2	10 493	143.0	0.230
Lean (g)	10 369	105.7	10 177	172.7	10 522	126.0	10 128	140.5	0.198
BMC (g)	366.9	10.0	375.4	16.3	356.5	11.9	364.6	13.2	0.845
BMD (g/cm^2)	0.69	0.01	0.68	0.02	0.67	0.01	0.68	0.01	0.630
Central FM (g)	1171	63.2	1280	103.3	1086	75.4	1336	84.0	0.165
Central Lean (g)	7023	74.4	6799	121.6	6899	88.7	6766	98.9	0.163
Central BMC (g)	261.8	6.8	269.2	11.1	246.8	8.1	264.7	9.0	0.380
Abdominal FM (g)	149	11.3	167	18.5	113	13.5	146	15.1	0.130
Thigh FM (g)	290	17.8	271	29.1	232	21.2	281	23.7	0.236
Abdominal/Thigh FM ratio	0.48	0.09	0.84	0.15	0.51	0.11	0.50	0.12	0.202
Arm FM (g)	187	13.4	181	21.9	169	16.0	205	17.9	0.519
Arm Lean (g)	817	21.9	786	35.8	915*†	26.1	819	29.1	0.024
Arm BMC (g)	23.2	1.3	23.6	2.2	24.6	1.6	23.4	1.8	0.926
Leg FM (g)	1055	40.7	1136	66.4	1017	48.5	1116	54.0	0.437
Leg Lean (g)	2530	53.4	2593	87.2	2708	63.6	2542	70.9	0.198
Leg BMC (g)	81.8	5.5	82.6	9.0	85.0	6.5	76.5	7.3	0.854

DEXA, dual X-ray absorptiometry; FFM, fat-free mass; FM, fat mass; Lean, lean mass; BMC, bone mineral content; BMD, bone mineral density; Abdominal/Thigh, abdominal fat mass to Thigh fat mass ratio; Total, whole body, Central, whole body, excluding arms and legs; Arm, arms region; Leg, legs region; Thigh, thigh region; Abdominal, abdominal region.

*Mean value was significantly different to European ($p < 0.05$).

†Mean value was significantly different to Indian ($p < 0.05$) (Tukey Comparison).

Further, 24-hour parental recalls of each child's food intake and activity patterns also found no differences by ethnicity or gender (Bristow, 2010). Accounting for ethnicity, height and weight at age 2 years, girls had higher total, central and percentage body fat and lower lean mass and bone mineral density than boys. The higher fat mass in girls was seen in the abdominal and thigh area of the body, but not in the arms.

Sexual dimorphism of body composition and growth are apparent from foetal life with differences particularly in lean and fat mass becoming most marked at puberty (Wells, 2007), but readily identified in early childhood (Cnattingius et al., 2012; Hadley & Hruschka, 2014; Shaw et al., 2007). Furthermore, body composition and growth patterns are programmed to a certain extent by early growth and fuel supply from the mother (Wells et al., 2007) and ecogeographical factors, such as climate, which can affect maternal size and consequently foetal growth and birth weight (Hadley & Hruschka, 2014). There are data showing that girls are more insulin resistant than boys at birth (Shields et al., 2007). Although we are unable to assess insulin resistance directly from our data, the higher abdominal adiposity in girls could be consistent with higher insulin resistance, especially if it was visceral fat (which cannot be shown by DEXA) (Hanley & Wagenknecht, 2008; Hayashi et al., 2008; Pou et al., 2009).

Gender differences varied within the ethnic groups studied. In Polynesian children, compared with the other ethnic groups, lean mass was greater in the arms of the girls and legs of the boys. In Indian children, the lower lean mass compared with other ethnicities only remained in boys after adjustment for height and weight. The fat storage in the Indian children was more of a central pattern of distribution, particularly compared with European children, where boys had significantly less central fat mass than the other ethnic

groups. Studies that have examined the ethnic differences in muscle mass and adiposity in school children (from age 5 years, using DEXA) have also found South Asians to have significantly higher percentages of body fat, particularly girls, compared to their African-Caribbean and European counterparts, despite having a ''normal'' BMI (Shaw et al., 2007).

No other study has examined ethnic differences in body composition of very young European, Indian and Polynesian children. The pattern of body composition differences seen by ethnicity is similar to that observed in adults of the same ethnic groups (Rush et al., 2009); however, we recognize that the small study population limits the significance of our findings, particularly for boys. The lack of a statistically detectable difference among boys may be due to a lack of power. This is especially important to note given that the ethnic-specific unadjusted mean values of lean mass for boys follow the same pattern of differences for girls, with Indian the least, Polynesian the most and European an intermediate value.

We speculate that the lower lean mass and higher central fat mass in Indian boys may reduce glucose disposal and increase insulin resistance, respectively, thus increasing their later risk of diabetes. On the other hand, in absolute terms Polynesian children aged 2–3 years weigh more than 1 kg more (>7%) than Indian, but their percentage fat mass is not statistically different to Indian, reflecting the accelerated growth of Polynesian children compared with international growth curves (Rush et al., 2013).

Although the aim of this report was to examine differences by ethnicity and gender, the original aim of the MiGTOFU study was to compare body composition of children whose mothers had been treated with metformin or insulin (Rowan et al., 2011). Ongoing follow-up of this MiGTOFU cohort will provide further data on body composition with age including measures of visceral fat and laboratory measurements of insulin sensitivity that may be related to the ethnic differences in fat distribution.

The study findings are limited by the cohort size, as there were relatively small numbers within each ethnicity when divided by gender. Secondly, our findings relate to offspring whose mothers received treatment for gestational diabetes and they may not be applicable to other groups. Other covariates such as maternal pre-pregnancy weight, birthweight, feeding and activity patterns of the children were measured and did differ by ethnicity (Bristow, 2010), but this analysis of ethnic differences in body composition did not account for these due to the relatively small sample size and group numbers and the preference to keep the analysis simple. Finally, measurement of total body composition by DEXA has its limitations, particularly in paediatric populations (Ellis et al., 1994), but at present and pragmatically (time and cost) it is the best tool available and we did exclude poor quality scans.

These initial findings provide early evidence underpinned by statistical certainty for gender and ethnic differences in the distribution of fat for 1–3 year old children born to mothers with GDM and may have implications for the prediction of risk for chronic disease including type 2 diabetes. Understanding the differences between diverse ethnic groups, especially at such a young age, might lead to appropriate assessments in children to identify who is most likely to benefit from intervention in the first few years of life to reduce risk of chronic disease including diabetes.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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